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(54) Title: COMPOUNDS FOR AND METHOD OF INHIBITING PHOSPHODIESTERASE IV

(57) Abstract

Novel compounds which are effective PDE IV inhibitors are disclosed. The compounds possess similar or improved PDE IV inhibition as compared to rolipram, with improved selectivity with regard to, e.g., PDE III inhibition. Preferred compounds are 3-(3-cyclopentyloxy-4-methoxy-benzylamino)-4-hydroxymethyl pyrazole and 3-(3-cyclopentyloxy-4-methoxybenzylamino)-4-methoxymethylpyrazole.

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COMPOUNDS FOR AND METHOD OF INHIBITING PHOSPHODIESTERASE IV

BACKGROUND OF THE INVENTION

Asthma is a complex disease involving the concerted actions of multiple inflammatory and immune cells, spasmogens, inflammatory mediators, cytokines and growth factors. In recent practice there have been four major classes of compounds used in the treatment of asthma, namely bronchodilators (e.g., β-adrenoceptor agonists), anti-inflammatory agents (e.g., corticosteroids), prophylactic anti-allergic agents (e.g., cromolyn sodium) and xanthines (e.g., theophylline) which appear to possess both bronchodilating and anti-inflammatory activity.

Theophylline has been a preferred drug of first choice in the treatment of asthma. Although it has been touted for its direct bronchodilatory action, theophylline's therapeutic value is now believed to also stem from anti-inflammatory activity. Its mechanism of action remains unclear. However, it is believed that several of its cellular activities are important in its activity as an anti-asthmatic, including cyclic nucleotide phosphodiesterase inhibition, adenosine receptor antagonism, stimulation of catecholamine release, and its ability to increase the number and activity of suppressor T-lymphocytes. While all of these actually may contribute to its activity, only PDE inhibition may account for both the anti-inflammatory and bronchodilatory components. However, theophylline is known to have a narrow therapeutic index, and a wide range of untoward side effects which are considered problematic.

Of the activities mentioned above, theophylline's activity in inhibiting cyclic nucleotide phosphodiesterase has received considerable attention

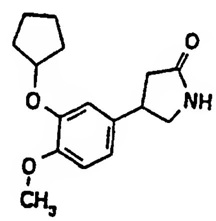
recently. Cyclic nucleotide phosphodiesterases (PDEs) have received considerable attention as molecular targets for anti-asthmatic agents. Cyclic 3',5'-adenosine monophosphate (cAMP) and cyclic 3',5'-guanosine monophosphate (cGMP) are known second messengers that mediate the functional responses of cells to a multitude of hormones, neurotransmitters and autocoids. At least two therapeutically important effects could result from phosphodiesterase inhibition, and the consequent rise in intracellular adenosine 3',5'-monophosphate (cAMP) or guanosine 3',5'-monophosphate (cGMP)in key cells in the pathophysiology of asthma. These are smooth muscle relaxation (resulting in bronchodilation) and anti-inflammatory activity.

It has become known that there are multiple, distinct PDE isoenzymes which differ in their cellular distribution. A variety of inhibitors possessing a marked degree of selectivity for one isoenzyme or the other have been synthesized.

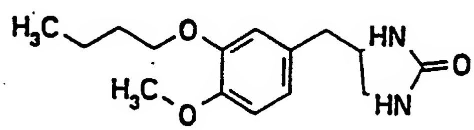
The structure-activity relationships (SAR) of isozyme-selective inhibitors has been discussed in detail, e.g., in the article of Theodore J. Torphy, et al., "Novel Phosphodiesterases Inhibitors For The Therapy Of Asthma", Drug News & Prospectives, 6(4) May 1993, pages 203-214. The PDE enzymes can be grouped into five families according to their specificity toward hydrolysis of cAMP or cGMP, their sensitivity to regulation by calcium, calmodulin or cGMP, and their selective inhibition by various compounds. PDE I is stimulated by Ca^{2+}/calmodulin. PDE II is cGMP-stimulated, and is found in the heart and adrenals. PDE III is cGMP-inhibited, and inhibition of this enzyme creates positive inotropic activity. PDE IV is cAMP specific, and its inhibition causes airway relaxation, antiinflammatory and

antidepressant activity. PDE V appears to be important in regulating cGMP content in vascular smooth muscle, and therefore PDE V inhibitors may have cardiovascular activity.

While there are compounds derived from numerous structure activity relationship studies which provide PDE III inhibition, the number of structural classes of PDE IV inhibitors is relatively limited. Analogues of rolipram, which has the following structural formula:



and of RO-20-1724, which has the following structural formula:



have been studied.

Rolipram, which was initially studied because of its activity as an antidepressant has been shown to selectively inhibit the PDE IV enzyme and this compound has since become a standard agent in the classification of PDE enzyme subtypes. There appears to be considerable therapeutic potential for PDE IV inhibitors. Early work focused on depression as a CNS therapeutic endpoint and on inflammation, and has subsequently been extended to include related diseases such as dementia and asthma.

In-vitro, rolipram, RO20-1724 and other PDE IV inhibitors have been shown to inhibit (1) mediator synthesis/release in mast cells, basophils, monocytes and eosinophils; (2) respiratory burst, chemotaxis and degranulation in neutrophils and eosinophils; and (3) mitogen-dependent growth and differentiation in lymphocytes (The PDE IV Family Of Calcium-Phosphodiesterases Enzymes, John A. Lowe, III, et al., Drugs of the Future 1992, 17(9):799-807).

PDE IV (and possibly PDE V) is present in all the major inflammatory cells in asthma including eosinophils, neutrophils, T-lymphocytes, macrophages and endothelial cells. Its inhibition causes down regulation of cellular activation and relaxes smooth muscle cells in the trachea and bronchus. On the other hand, inhibition of PDE III, which is present in myocardium, causes an increase in both the force and rate of cardiac contractility. These are undesirable side effects for an anti-inflammatory agent. Theophylline, a non-selective PDE inhibitor, inhibits both PDE III and PDE IV, resulting in both desirable anti-asthmatic effects and undesirable cardiovascular stimulation. With this well-known distinction between PDE isozymes, the opportunity for concomitant anti-inflammation and bronchodilation without many of the side effects associated with theophylline therapy is apparent. The increased incidence of morbidity and mortality due to asthma in many Western countries over the last decade has focused the clinical emphasis on the inflammatory nature of this disease and the benefit of inhaled steroids. Development of an agent that possesses both bronchodilatory and antiinflammatory properties would be most advantageous.

It appears that selective PDE IV inhibitors should be more effective with fewer side effects than

theophylline. Clinical support has been shown for this hypothesis.

Attempts have therefore been made to find new compounds having more selective and improved PDE IV inhibition.

OBJECTS AND SUMMARY OF THE INVENTION

It is accordingly a primary object of the present invention to provide new compounds which are effective PDE IV inhibitors.

It is another object of the present invention to provide new compounds which act as effective PDE IV inhibitors with lower PDE III inhibition.

It is a further object of the present invention to provide new compounds which have a superior PDE IV inhibitory effect as compared to rolipram or other known compounds.

It is a further object of the present invention to provide new compounds which have a substantially equal or superior PDE IV inhibitory effect as compared to known chemical compounds, and which exhibit surprisingly greater selectivity with regard to their inhibitory effects.

It is another object of the present invention to provide a method of treating a patient requiring PDE IV inhibition.

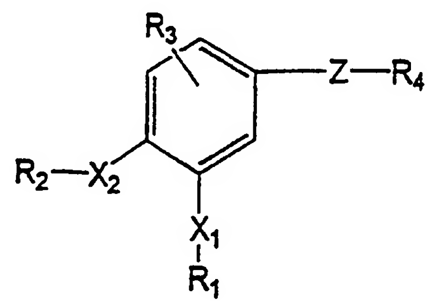
It is another object of the present invention to provide new compounds for treating disease states associated with abnormally high physiological levels of cytokine, including tumor necrosis factor.

It is another object of the present invention to provide a method of synthesizing the new compounds of this invention.

It is another object of the present invention to provide a method for treating a mammal suffering from a

disease state selected from the group consisting of asthma, allergies, inflammation, depression, dementia and disease states associated with abnormally high physiological levels of cytokine.

With the above and other objects in view, the present invention mainly comprises a compound of the formula:



wherein:

X_1 and X_2 may be the same or different and each is O or S;

R_1 and R_2 may be the same or different and each are saturated or unsaturated straight-chain or branched alkyl groups containing from 1 to 12 carbon atoms, cycloalkyl and cycloalkyl-alkyl groups containing from 3 to 7 carbon atoms in the cycloalkyl moiety; and aryl and arylalkyl groups preferably containing from 6 to 10 carbon atoms, which are unsubstituted or substituted by lower alkyl groups having from 1 to 3 carbon atoms, one or more halogen atoms, hydroxyl groups, cyano groups, nitro groups, carboxyl groups, alkoxy groups, alkoxycarbonyl, carboxamido or substituted or unsubstituted amino groups, or heterocyclic groups containing one or more of nitrogen, oxygen and/or sulfur in the ring, or one of R_1 and R_2 are hydrogen and the other represents a hydrocarbon group as set forth above;

R_3 is hydrogen, halogen or a saturated or unsaturated straight-chain or branched alkyl group containing from 1 to 12 carbon atoms, a cycloalkyl and cycloalkyl-alkyl groups containing from 3 to 7 carbon atoms in the cycloalkyl moiety; or an aryl or aralkyl group preferably containing from 6 to 10 carbon atoms, which groups are unsubstituted or substituted by one or more halogen atoms, hydroxyl groups, cyano groups, nitro groups, carboxyl groups, alkoxy groups, alkoxycarbonyl, carboxamido or substituted or unsubstituted amino groups, or heterocyclic groups containing one or more of nitrogen, oxygen or sulfur in the ring;

Z is a bond or a bridging (linking) group containing from 1 to 3 carbon atoms, wherein one of the carbon atoms in the bridging group may be replaced by nitrogen, oxygen or sulfur. The carbon atoms in the bridging group may be saturated or unsaturated and may be unsubstituted or substituted with one or more substituents selected from halogen atoms (e.g., chlorine, bromine, fluorine, iodine), lower alkyl groups having from 1 to 3 carbon atoms, hydroxyl groups, cyano groups, carboxyl groups, alkoxy groups, carbonyl groups, alkoxycarbonyl groups, or substituted or unsubstituted amino groups;

R_4 is a 5-membered heterocyclic group which contains one or more or nitrogen, oxygen and/or sulfur atoms. The heterocyclic group may be unsubstituted or substituted with one or more halogen atoms, C_{1-4} alkyl hydroxyl groups, cyano groups, nitro groups, carboxyl groups, C_{1-4} alkoxylcarbonyl groups, alkoxy groups, alkoxycarbonyl, amido, carboxamido, or substituted or unsubstituted amino groups. The heterocyclic group may also be substituted with alkyl, cycloalkyl and cycloalkyl-alkyl groups containing from 3 to 7 carbon atoms in the cycloalkyl moiety, aryl or arylalkyl groups preferably containing

from about 6 to about 10 carbon atoms, or heterocyclic groups containing nitrogen, oxygen or sulfur in the ring, which groups are unsubstituted or substituted by halogen atoms, hydroxyl groups, cyano groups, carboxyl groups, C_{1-4} alkoxy groups, alkoxycarbonyl, carboxamido or substituted or unsubstituted amino groups, or one or more lower alkyl groups having from 1 to 3 carbon atoms; provided that R_4 is other than 4-imidazolinone or 4-pyrolidinone.

The term "lower alkyl" is defined for purposes of the present invention as straight or branched chain radicals having from 1 to 3 carbon atoms.

DETAILED DESCRIPTION

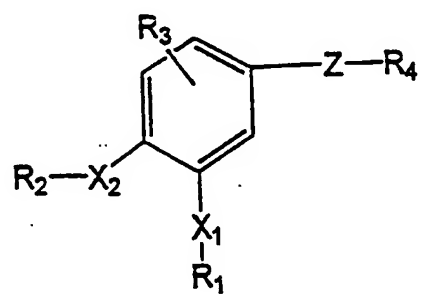
The compounds of the present invention, as demonstrated in the appended examples, are effective in the mediation or inhibition of PDE IV in humans and other mammals. Further, these compounds are selective PDE IV inhibitors which possess both bronchodilatory and antiinflammatory properties substantially without undesirable cardiovascular stimulation caused by PDE III inhibition. Many of these compounds have a substantially equal or superior PDE IV inhibitory effect as compared to theophylline.

The present invention is further related to a method for the treatment of allergic and inflammatory disease which comprises administering to a mammal in need thereof an effective amount of the compounds of the present invention.

The present invention is also related to a method for the mediation or inhibition of the enzymatic or catalytic activity of PDE IV activity in mammals, particularly humans, which comprises administering an effective amount of the above-described compounds of the invention to a mammal in need of PDE IV inhibition.

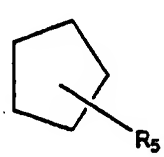
The compounds of the present invention may find use in the treatment of other disease states in humans and other mammals, such as in the treatment of disease states associated with a physiologically detrimental excess of tumor necrosis factor (TNF). TNF activates monocytes, macrophages and T-lymphocytes. This activation has been implicated in the progression of Human Immunodeficiency Virus (HIV) infection and other disease states related to the production of TNF and other cytokines modulated by TNF.

In certain preferred embodiments, the compounds of the present invention comprise the formula:



wherein:

R_2 is hydrogen or branched or straight chain alkyl of 1-12 carbon atoms, preferably lower alkyl, most preferably methyl or ethyl, and R_1 is alkyl of 1-12 carbon atoms, which may be substituted by one or more halogens, or cycloalkyl of 3-6 carbon atoms, preferably cyclopentyl which may be substituted by R_5 as shown in the following structural formula:



wherein R_5 is hydrogen or a saturated or unsaturated straight-chain lower alkyl group containing from about 1 to about 6 carbon atoms, unsubstituted or substituted with one or more halogen atoms, hydroxyl groups, cyano groups, nitro groups, carboxyl groups, alkoxy groups, alkoxycarbonyl, carboxamido or substituted or unsubstituted amino groups;

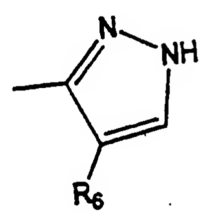
R_3 is hydrogen, lower alkyl or halogen;

Z is a linkage selected from a bond, -NH-, $-CH_2-$, $-CH_2CH_2-$, $-CH_2NH-$, $CH_2N(Me)$, $NHCH_2-$, -NH-, $-CH_2CONH-$, $-NHCH_2CO-$, $-CH_2CO-$, $-COCH_2-$, $-CH_2COCH_2-$, $-CH(CH_3)-$, -CH=, and -HC=CH-;

X_1 and X_2 may be the same or different and each is O or S; and

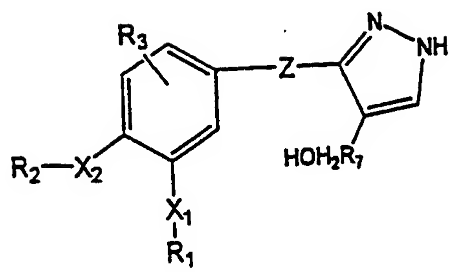
R_4 is an unsubstituted or substituted pyrazole, imidazole, or triazole as set forth previously.

In one preferred embodiment, R_4 is a substituted pyrazole having the following structure:



wherein R_6 is a substituted or unsubstituted lower alkyl having from about 1 to about 3 carbon atoms.

In a particularly preferred embodiment of the present invention, the compounds have the formula:



where X_1 and X_2 may be the same or different and each is O or S;

R_1 is alkyl of 1-12 carbon atoms or cycloalkyl of 3-6 carbon atoms, which cycloalkyl may be substituted by one or more alkyl groups or by one or more halogens;

R_2 is hydrogen or alkyl of 1-12 carbon atoms;

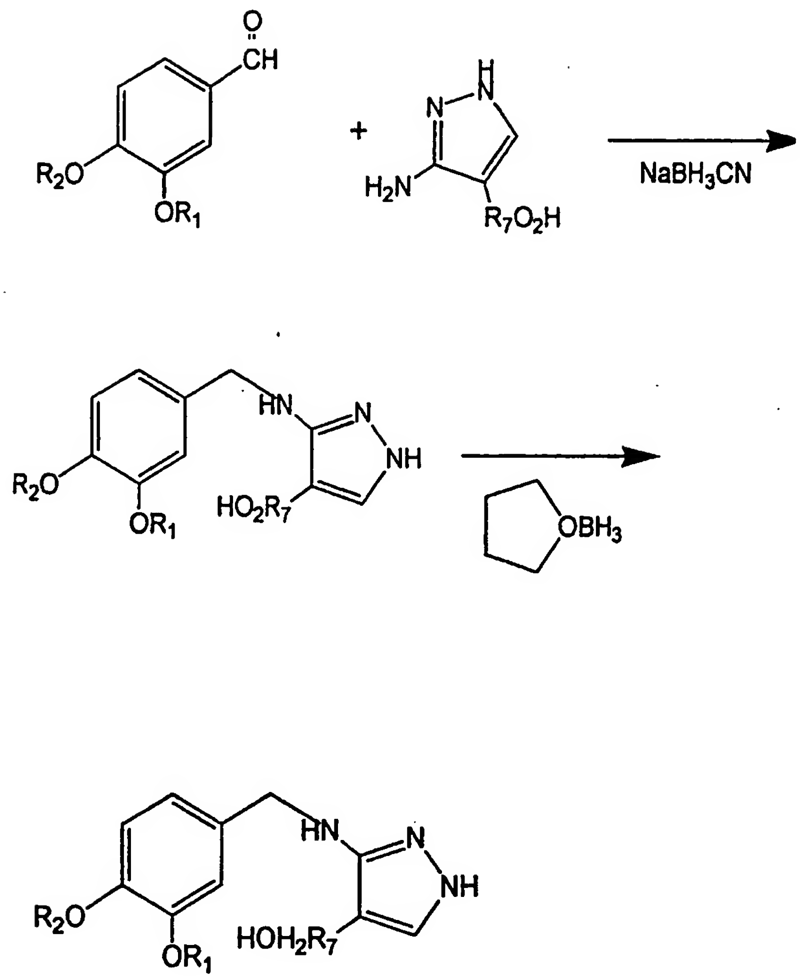
R_3 is hydrogen, lower alkyl or halogen;

Z is a linkage selected from a bond, -NH-, $-CH_2-$, $-CH_2CH_2-$, $-CH_2NH-$, $NHCH_2-$, -NH-, $-CH_2N(Me)-$, $-CH_2CONH-$, $-NHCH_2CO-$, $-CH_2CO-$, $-COCH_2-$, $-CH_2COCH_2-$, $-CH(CH_3)-$, -CH=, and -HC=CH-; and

R_7 is C or CH_2C.

One preferred compound of the present invention is 3-(3-cyclopentyloxy-4-methoxybenzylamino)-4-hydroxymethyl pyrazole.

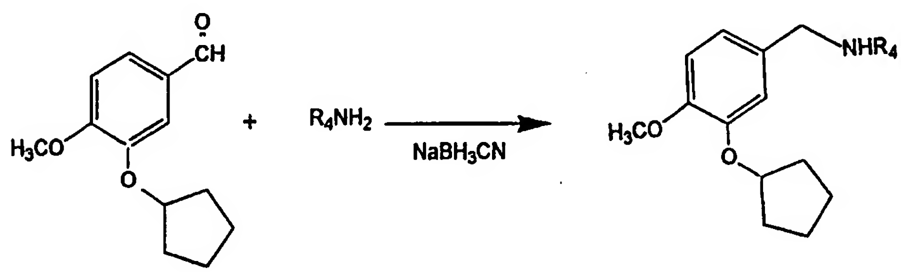
In certain preferred embodiments, compounds of the present invention are prepared by the two-step process shown below for the preferred compound of the invention, 3-(3-cyclopentyloxy-4-methoxybenzylamino)-4-hydroxymethyl pyrazole.



The condensation of 3-cyclopentyloxy-4-methoxybenzaldehyde with 3-amino-4-pyrazolecarboxylic acid in the presence of sodium cyanoborohydride produces 3-(3-cyclopentyloxy-4-methoxybenzylamino)-4-pyrazolecarboxylic acid in 48% yield. Treatment with excess borane-tetrahydrofuran complex in tetrahydrofuran

solution gives 3-(3-cyclopentyloxy-4-methoxybenzylamino)-4-hydroxymethylpyrazole (Example 1) in 40% yield.

In other embodiments where R_4 is an imidazole, triazole or pyrazole, the compounds can be synthesized by reductively condensing 3-cyclopentyloxy-4-methoxybenzaldehyde with amino heterocycles using sodium cyanoborohydride. The reaction is shown below.



The compounds of the present invention have been found to be highly effective PDE IV inhibitors, the inhibition of which is in fact significantly and surprisingly greater than that of theophylline.

Thus, the concentration which yields 50% inhibition of PDE IV (IC_{50}) for 3-(3-cyclopentyloxy-4-methoxybenzylamino)-4-hydroxymethyl pyrazole is 16 nM (0.016 μM), whereas the IC_{50} for rolipram when run in the same assay was 4.5 μM. Historically, the IC_{50} for rolipram is considered to be 3.5 μM. In any case, it is apparent that Example 1 of the present invention is several hundred times as effective as a PDE IV inhibitor as compared to rolipram.

By comparison, PDE III inhibition of Example 1 of the present invention is within 1 order of magnitude of that of rolipram, and therefore relative to the percentage increase in PDE IV inhibition, it is clear

that the compound of the invention is much more highly selective as a PDE IV inhibitor than rolipram.

Accordingly, the compounds of the present invention can be administered to anyone requiring PDE IV inhibition. Administration may be orally, topically, by suppository, inhalation or insufflation, or parenterally.

The present invention also encompasses all pharmaceutically acceptable salts of the foregoing compounds. One skilled in the art will recognize that acid addition salts of the presently claimed compounds may be prepared by reaction of the compounds with the appropriate acid via a variety of known methods. Alternatively, alkali and alkaline earth metal salts are prepared by reaction of the compounds of the invention with the appropriate base via a variety of known methods. For example, the sodium salt of the compounds of the invention can be prepared via reacting the compound with sodium hydride.

Various oral dosage forms can be used, including such solid forms as tablets, gelcaps, capsules, caplets, granules, lozenges and bulk powders and liquid forms such as emulsions, solution and suspensions. The compounds of the present invention can be administered alone or can be combined with various pharmaceutically acceptable carriers and excipients known to those skilled in the art, including but not limited to diluents, suspending agents, solubilizers, binders, disintegrants, preservatives, coloring agents, lubricants and the like.

When the compounds of the present invention are incorporated into oral tablets, such tablets can be compressed, tablet triturates, enteric-coated, sugar-coated, film-coated, multiply compressed or multiply layered. Liquid oral dosage forms include aqueous and nonaqueous solutions, emulsions, suspensions,

and solutions and/or suspensions reconstituted from non-effervescent granules, containing suitable solvents, preservatives, emulsifying agents, suspending agents, diluents, sweeteners, coloring agents, and flavorings agents. When the compounds of the present invention are to be injected parenterally, they may be, e.g., in the form of an isotonic sterile solution. Alternatively, when the compounds of the present invention are to be inhaled, they may be formulated into a dry aerosol or may be formulated into an aqueous or partially aqueous solution.

In addition, when the compounds of the present invention are incorporated into oral dosage forms, it is contemplated that such dosage forms may provide an immediate release of the compound in the gastrointestinal tract, or alternatively may provide a controlled and/or sustained release through the gastrointestinal tract. A wide variety of controlled and/or sustained release formulations are well known to those skilled in the art, and are contemplated for use in connection with the formulations of the present invention. The controlled and/or sustained release may be provided by, e.g., a coating on the oral dosage form or by incorporating the compound(s) of the invention into a controlled and/or sustained release matrix.

Specific examples of pharmaceutically acceptable carriers and excipients that may be used for formulate oral dosage forms, are described in the Handbook of Pharmaceutical Excipients, American Pharmaceutical Association (1986), incorporated by reference herein. Techniques and compositions for making solid oral dosage forms are described in Pharmaceutical Dosage Forms: Tablets (Lieberman, Lachman and Schwartz, editors) 2nd edition, published by Marcel Dekker, Inc., incorporated

by reference herein. Techniques and compositions for making tablets (compressed and molded), capsules (hard and soft gelatin) and pills are also described in Remington's Pharmaceutical Sciences (Arthur Osol, editor), 1553-1593 (1980), incorporated herein by reference. Techniques and composition for making liquid oral dosage forms are described in Pharmaceutical Dosage Forms: Disperse Systems, (Lieberman, Rieger and Banker, editors) published by Marcel Dekker, Inc., incorporated herein by reference.

When the compounds of the present invention are incorporated for parenteral administration by injection (e.g., continuous infusion or bolus injection), the formulation for parenteral administration may be in the form of suspensions, solutions, emulsions in oily or aqueous vehicles, and such formulations may further comprise pharmaceutically necessary additives such as stabilizing agents, suspending agents, dispersing agents, and the like. The compounds of the invention may also be in the form of a powder for reconstitution as an injectable formulation.

The dose of the compounds of the present invention is dependent upon the affliction to be treated, the severity of the symptoms, the route of administration, the frequency of the dosage interval, the presence of any deleterious side-effects, and the particular compound utilized, among other things.

The PDE IV inhibitory compounds of the present invention may be examined for their PDE IV inhibitory effects via the techniques set forth in the following examples, wherein the ability of the compounds to inhibit PDE IV isolated from bovine tracheal smooth muscle is set forth.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

The following examples illustrate various aspects of the present invention, and are not to be construed to limit the claims in any manner whatsoever.

EXAMPLE 1

3-(3-cyclopentyloxy-4-methoxy benzylamino)-4-hydroxymethylpyrazole

The above-mentioned compound was prepared by a two-step process as set forth below:

A: 3-(3-cyclopentyloxy-4-methoxy-benzylamino)-4-pyrazolecarboxylic acid

A suspension of 3-amino-4-pyrazole carboxylic acid (3.56 g, 28 mmol) in 400 ml of methanol and 3-cyclopentyloxy-4-methoxybenzaldehyde (5.06 g, 23 mmol) was stirred at room temperature for 16 hours with sodium cyanoborohydride, 1.85 g (95% pure, 28 mmol). The methanol was evaporated under reduced pressure and the residue was taken up in 100 ml of 15% sodium hydroxide and extracted twice with 100 ml portions of ether. The aqueous layer was acidified to pH 5 with 5 N hydrochloric acid and extracted twice with 100 ml portions of ethyl acetate. The ethyl acetate was dried over sodium sulfate and evaporated. The residue was triturated with ether to give 3.7 g of 3-(3-cyclopentyloxy-4-methoxybenzylamino)-4-pyrazolecarboxylic acid (48.7%). Pure 3-(3-cyclopentyloxy-4-methoxybenzylamino)pyrazole carboxylic acid shows mp. 134-136°C after crystallization from methanol.

B: 3-(3-cyclopentyloxy-4-methoxybenzylamino)-4-hydroxymethylpyrazole

Pure 3-(3-cyclopentyloxy-4-methoxybenzylamino)-4-pyrazolecarboxylic acid (compound 3) (1.32 g, 4.0 mmol) was dissolved in 50 ml of THF and cooled to -15°C under nitrogen. Borane-tetrahydrofuran (30 ml of 1 M solution,

30 mmol) was added over 30 minutes and the resulting solution was stirred for 72 hours at room temperature. Methanol (30 ml) was added to the reaction and the solvent was evaporated under reduced pressure. The residue was treated with 160 ml of methanol and evaporated again. The crude product was treated with 30 ml of 10% aqueous ammonia and some brine and then extracted with three 50 ml portions of ethyl acetate. Evaporation of the solvent afforded 1.1 g of crude 3-(3-cyclopentyloxy-4-methoxybenzylamino)-4-hydroxymethylpyrazole which was purified by flash chromatography on 30 g of flash chromatography silica gel. Elution with ethyl acetate/hexane (1:4) afforded a small amount of material which was discarded. Elution with 60 ml of 1:1 ethyl acetate/hexane gave 600 mg of 3-(3-cyclopentyloxy-4-methoxybenzylamino)-4-hydroxymethylpyrazole which was recrystallized from 2 ml of toluene to give 500 mg of pure 3-(3-cyclopentyloxy-4-methoxybenzylamino)-4-hydroxymethylpyrazole (compound 4) mp 129-130°C.

EXAMPLE 2

3-(3-Cyclopentyloxy-4-methoxybenzyl-amino)-4-pyrazolecarboxamide

To a stirred suspension of 3-amino-4-pyrazolecarboxamide hemisulfate (0.005 mole) was added 0.14 g of potassium hydroxide (KOH), 3-cyclopentyloxy-4-methoxybenzaldehyde (0.88 g, 0.004 mole), and 95% sodium cyanoborohydride (0.33 g, 0.004 mol). Stirring was continued at room temperature for 24 hours after which KOH (0.56 g) was added and the solvent was evaporated under reduced pressure. The residue was treated with 50 ml of brine and extracted twice with 50 ml portions of ethyl acetate. The ethyl acetate was evaporated under reduced pressure and the residue was triturated with

ether to give 0.4g of the crude title compound. Crystallization from 15 ml of acetone gave 0.25 g (15%) of the pure title compound, mp 128-130°C.

EXAMPLE 3

3-(3-Cyclopentyloxy-4-methoxybenzylamino)-1,2,4-triazole

To a stirred solution of 3-amino-1,2,4-triazole (1.5 g, 0.018 mol), 7.5 ml of 1 N HCl, and 50 ml of methanol was added 3-cyclopentyloxy-4-methoxybenzaldehyde (3.3 g, 0.015 mol) and sodium cyanoborohydride (0.945 g, 0.015 mol). A precipitate formed slowly and after 20 hours the precipitate was filtered and recrystallized from methanol (135 ml) to give 1.0 g (0.0034 mol, 23%) of the title compound, mp 203-204°C.

Example 4

3-(3-Cyclopentyloxy-4-methoxybenzylamino)pyrazole

To a solution of 3-aminopyrazole (1.5 g, 0.018 mol) in 50 ml of methanol and 7.5 ml of 1N aqueous HCl was added 3-cyclopentyloxy-4-methoxybenzaldehyde (3.3 g, 0.015 mol) and 95% sodium cyanoborohydride (1.0 g, 0.015 mol). The solution was stirred at room temperature for 20 hours after which concentrated aqueous hydrochloric acid (Hcl) was added to pH 2. The solvent was evaporated at reduced pressure and the residue was extracted twice with 50 ml portions of ether. The ether extracts were discarded and the aqueous solution was brought to pH 10 with 5N aqueous NaOH. The mixture was extracted twice with 50 ml portions of ethyl acetate. The combined ethyl acetate extracts were dried ($MgSO_4$) and evaporated. The solid residue was triturated with ether to give the pure title compound (1.3 g, 30%), mp 106-110°C.

Example 5

5-(3-Cyclopentyloxy-4-methoxybenzylamino)-1,2,3-triazole

To a stirred solution of 5-amino-1,2,3-triazole (3.0 g, 0.036 mol) in 100 ml of methanol and 15 ml of 1 N HCl was added sodium cyanoborohydride (1.89 g, 0.030 mol) and 3-cyclopentyloxy-4-methoxybenzaldehyde (6.6 g, 0.30 mol). The reaction mixture was stirred at room temperature for 64 hours and then acidified to pH 2 with concentrated HCl. The solution was evaporated at reduced pressure and the residue was treated with water (100 ml) and extracted twice with 100 ml portions of ethyl acetate. The ethyl acetate extracts were combined and extracted twice with 50 ml portions of 3N HCl and then discarded. The aqueous extracts were combined with the original aqueous layer and basified to pH 12 with potassium hydroxide pellets. The alkaline solution was extracted twice with 100 ml portions of ethyl acetate. The ethyl acetate extracts were combined and evaporated to give a solid which was crystallized from ethyl acetate to give 2.9 g (34%) of the title compound mp 113-114°C collected in two crops.

Example 6

2-(3-Cyclopentyloxy-4-methoxybenzylamino)imidazole

A stirred suspension of 2-aminoimidazole sulfate (5.67 g, 0.043 mol) in 100 ml of methanol was treated with solid KOH (0.65 g, 0.011 mol) followed by 3-cyclopentyloxy-4-methoxybenzaldehyde (7.26 g, 0.033 mol). To this mixture was added dropwise over 30 minutes solution of 95% sodium cyanoborohydride (2.2 g, 0.33 mol) in methanol (30 ml). The reaction mixture was stirred at room temperature for 64 hours after which solid KOH (2.45 g, 0.055 mol) was added. After the KOH had dissolved, the mixture was filtered and the filtrate was evaporated

under reduced pressure. The residue was treated with saturated NaCl and extracted three times with 50 ml portions of ethyl acetate. The combined ethyl acetate extracts were extracted twice with 5N aqueous HCl. Evaporation of the ethyl acetate yielded 5.5 g of unreacted 3-cyclopentyloxy-4-methoxybenzaldehyde. The aqueous HCl extract was basified to pH 12 with solid KOH and extracted twice with 50 ml portions of ethyl acetate. Evaporation of the ethyl acetate afforded 2.4 g of a brown oil which was purified by flash chromatography over 40 g of flash chromatography silica gel. Elution with methylene chloride-methanol mixtures afforded 1.8 g of the title compound eluted with 5% methanol-methylene chloride. The 1.8 g of material was treated with solution of picric acid (5 g, 0.021 mol) in 50 ml of ethanol. The picrate (1.9 g) was collected and recrystallized from 25 ml of ethanol to give 1.7 g of the pure picrate. The picrate (1.5 g) was dissolved in 200 ml of ethyl acetate and extracted 5 times with 25 ml portions of 2N aqueous LiOH. The ethyl acetate solution was evaporated and the residue (0.9 g) was purified by flash chromatography over 40 g of silica gel, eluting with methanol-methylene chloride mixtures to give 0.5 g of the material which was crystallized from 15 ml of ethyl acetate to give 0.3 g (3%) of the pure title compound, mp 114-115oC.

Example 7

3-(3-Cyclopentyloxy-4-methoxybenzyl-amino)-4-pyrazolecarboxylic acid

To a suspension of 3-aminopyrazole-4-carboxylic acid (3.56 g, 0.023 mol) in 400 ml of methanol was added 3-cyclopentyloxy-4-methoxybenzaldehyde (5.06 g, 0.023 mole) and 95% sodium cyanoborohydride (1.85 g, 0.028 mol). The reaction mixture was stirred for 16 hours and then the

methanol was evaporated under reduced pressure. The residue was treated with 100 ml of 15% aqueous NaOH and extracted twice with 100 ml portions of ether. The aqueous layer was acidified to pH 5 with 5 N aqueous HCl and extracted twice with 100 ml portions of ethyl acetate. The ethyl acetate extracts were evaporated under reduced pressure and the residue was triturated with ether to give 3.7 g (49%) of the title compound, mp 134-136°, after recrystallization from methanol.

EXAMPLE 8

5-(3-Cyclopentyloxy-4-methoxybenzal)hydantoin

To a stirred solution of diethyl 5-hydantoylphosphonate (10 g, 42.3 mmol) and triethylamine (5.70 g, 56 mmol), in dry acetonitrile (100 ml), at room temperature was added a solution of 3-cyclopentyloxy-4-methoxybenzaldehyde (8 g, 36.3 mmol) in dry acetonitrile (75 ml), dropwise over 30 minutes. The resulting mixture was stirred at room temperature overnight, after which volatiles were removed in vacuo. The residue was diluted with 0.05N HCl (120 ml) and the precipitate collected by filtration. Recrystallization of this material with methylene chloride/methanol/diethyl ether afforded the title compound as a pale yellow solid (8.54 g). m.p. 220-222°C.

^{1}H NMR ($CDCl_3$; 250 MHz) δ 7.72 (brs, 1H), 7.66 (brs, 1H), 6.90 (m, 3H), 6.66 (s, 1H), 4.79 (m, 1H), 3.88 (s, 3H), 1.84 (m, 6H), 1.62 (m, 2H).

EXAMPLE 9

4-(3-Cyclopentyloxy-4-methoxybenzyl)-5-methyl-pyrazol-3-one

A. (E)/(Z)Ethyl 2-acetyl-3-(3-cyclopentyloxy-4-methoxyphenyl)-2-propenoate

To a stirred solution of 3-cyclopentyloxy-4-methoxybenzaldehyde (4.0 g, 22.69 mmol) and ethyl acetoacetate (2.95 g, 22.67 mmol) in benzene (60 ml) were added piperidine (104 mg, 1.22 mmol) and glacial acetic acid (286 mg, 4.76 mmol) in one portion. The resulting solution was refluxed at 85°C for 3 hours with continuous removal of water. Further piperidine (208 mg, 2.44 mmol) and glacial acetic acid (858 mg, 14.28 mmol) were added and refluxing continued for a further 5 hours. The mixture was cooled to room temperature and diluted with diethyl ether (300 ml). The organics were washed successively with 5% aqueous HCl (100 ml) and water (2 x 100 ml). The resulting etheral extracts were dried (Na_2SO_4) and concentrated in vacuo to give a deep orange oil. The oil was purified by flash chromatography (SiO_2; ethyl acetate/hexane (3:7)) to afford the title compound as an orange oil (983 mg).

^{1}H ($CDCl_3$; 250 MHz) δ 7.57 and 7.46 (2s, 1H), 6.92 (m, 3H), 6.92 (m, 3H), 4.70 (m, 1H), 4.34 and 4.26 (2q, 2H), 3.87 and 3.86 (2s, 3H), 2.39 and 2.37 (2s, 3H), 1.87 (m, 6H), 1.62 (m, 2H), 1.31 (t, 3H).

B. Ethyl 2 acetyl-3-(3-cyclopentyl-oxy-4-methoxyphenyl)-propanoate

A solution of (E)/(Z) ethyl 2-acetyl-3-(3-cyclopentyloxy-4-methoxyphenyl)-2-propenoate (745 mg, 2.24 mmol) in ethyl acetate (20 ml) containing palladium on activated carbon (10% palladium, 25 mg) was hydrogenated at 40 p.s.i. for 5 hours at room temperature. The mixture was filtered through celite and

the filter cake washed with ethyl acetate (2 x 25 ml). The filtrate was concentrated in vacuo and purified by flash chromatography (SiO_2; ethyl acetate/ hexane (3:7)) to afford the title compounds as a pale yellow oil (585 mg).

R_f (SiO_2; ethyl acetate/hexane (3:7)) 0.45.

C. 4-(3-Cyclopentyloxy-4-methoxy-benzyl)-5-methyl-pyrazol-3-one

To a stirred solution of ethyl 2-acetyl-3-(3-cyclopentyloxy-4-methoxyphenyl)-propanoate (585 mg, 1.74 mmol) in absolute ethanol (10 ml) at 0°C was added hydrazine monohydrate (87 mg, 1.74 mmol) in one portion. The resulting solution was stirred at 0°C for 45 minutes and then refluxed at 80°C for 3 hours. After cooling to room temperature, the reaction mixture was concentrated in vacuo and purified by flash chromatography (SiO_2;methylene chloride/ ethanol/ammonia (4:1:0.1)) to afford the title compound as a white solid (343 mg). m.p. 186-187°C.

^1H NMR (CD_3OD; 250 MHz) δ 6.78 (m, 3H), 4.73 (m, 1H), 3.76 (s, 3H), 3.56 (s, 2H), 2,03 (s, 3H), 1.80 (m, 6H), 1.59 (m, 2H).

EXAMPLE 10

4-[1-(3-Cyclopentyloxy-4-methoxy-phenyl)ethyl]-5-methyl-pyrazol-3-one

A. N-Methoxy-N-methyl-3-(3-cyclopentyloxy-4-methoxyphenyl)-prop-2-enamide

To a stirred solution of diethyl(N-methoxy-N-methylcarbamoylmethyl)phosphonate (2.60 g, 10.90 mmol) in dry tetrahydrofuran (50 ml) at -78°C was added lithium diisopropylamide (1.5M solution in cyclohexane, 7.33 ml, 11 mmol) dropwise over 3 minutes. The resulting solution was stirred at -78°C for 30 minutes, after which time 3-

cyclopentyloxy-4-methoxybenzaldehyde (1.5 g, 6.81 mmol) in dry tetrahydrofuran (5 ml) was added in one portion. The reaction was allowed to warm to room temperature and stirring continued overnight. After which time the reaction mixture was diluted with water (25 ml) and the tetrahydrofuran removed in vacuo. The aqueous residue was diluted with brine (25 ml) and extracted with methylene chloride (3 x 60 ml). The organic extracts were dried (Na_2SO_4) and evaporated in vacuo to give a yellow liquid. The liquid was purified by flash chromatography (SiO_2; hexane/ethyl acetate (65:35)) to afford the title compound as a pale yellow liquid (1.986 g).

R_f (SiO_2; ethyl acetate/hexane (35:65)) 0.15

B. <u>(E)-4-(3-Cyclopentyloxy-4-methoxyphenyl)-3-buten-2-one</u>

To a stirred solution of N-methoxy-N-methyl-3-(3-cyclopentyloxy-4-methoxyphenyl)prop-2-enamide (1.986 g, 6.50 mmol) in dry tetrahydrofuran (15 ml) at -78°C was added methyl lithium (1.4M solution in hexanes, 10.20 ml, 14.3 mmol) dropwise over 3 minutes. The resulting solution was stirred for 1 hour at 0°C, after which time the reaction mixture was diluted with 5% HCl in methanol (20 ml) at 0°C, and partitioned between brine (35 ml) and an equal volume of methylene chloride and diethyl ether (100 ml). The organics were dried (Na_2SO_4) and concentrated in vacuo to give a light yellow oil. The oil was purified by flash chromatography (SiO_2; ethyl acetate/hexane (35:65)) to afford the title compound as a colorless oil (1.642 g).

^1H NMR ($CDCl_3$; 250 MHz) δ 7.43 (d, J=16.2Hz, 1H), 7.08 (m, 2H), 6.85 (d, 1H), 6.57 (d, J=16.2Hz, 1H), 4.78 (m, 1H), 3.87 (s, 3H), 2.36 (s, 3H), 1.89 (m, 6H), 1.62 (m, 2H).

C. [[4-(3-Cyclopentyloxy-4-methoxyphenyl)-2-penten-2-yl]oxy]tributylsilane

To a stirred suspension of cuprous iodide (1.15 g, 6.045 mmol) in dry tetrahydrofuran (10 ml) at 0°C was added methyl lithium (1.4M solution in hexanes, 8.635 ml, 12.09 mmol) dropwise over 3 minutes. The resulting solution was stirred at 0°C for 30 minutes, then cooled to -78°C and chlorotributylsilane (3.54 g, 15.07 mmol) in dry tetrahydrofuran (5 ml) added so that the temperature of the reaction mixture did not rise above -60°C. After addition was complete the reaction was stirred at -78°C for 10 minutes then (E)-4-(3-cyclopentyloxy-4-methoxyphenyl)-3-buten-2-one (787 mg, 3.02 mmol) in dry tetrahydrofuran (5 ml) added dropwise over 3 minutes. The resulting solution was stirred at -78°C for 45 minutes and quenched at -78°C by the addition of aqueous saturated $NaHCO_3$ (25 ml) and water (20 ml).

After warming to room temperature, the precipitate was removed by filtration and the filtrate extracted with pentane (3 x 70 ml). The organics were washed with water (20 ml), brine (20 ml) and dried (Na_2SO_4) and concentrated in vacuo to give an oil. The oil was purified by flash chromatography (SiO_2;1) hexane 2) hexane/ ethyl acetate (9:1)) to afford the title compound (contaminated with tributylsilane/chlorotributylsilane) as a colorless oil (3.33g). R_f (SiO_2; hexane/ethyl acetate (9:1)) 0.42

D. Methyl 2-acetyl-3-(3-cyclopentyloxy-4-methoxyphenyl)-butanoate

To a stirred solution of [[4-(3-(cyclopentyloxy-4-methoxyphenyl)-2-penten-2-yl]oxy]tributylsilane prepared as detailed above, (3.38 g, containing approximately 3.0 mmol of the desired compound and 8.0 mmol of chlorotributylsilane/tributylsilane) in dry tetrahydrofuran (10 ml) at 0°C was added methyl lithium

(1.4M in diethyl ether, 9.37 ml, 13.12 mmol) dropwise over 3 minutes. The resulting clear solution was stirred for 18 hours at room temperature, then cooled to -78°C. Hexamethylphosphoramide (537 mg, 3.0 mmol) and methylcyanoformate (280 mg, 3.3 mmol) in dry tetrahydrofuran (3 ml) were added and the mixture stirred at -78°C for 30 minutes. After warming to 0°C the reaction mixture was portioned between water (40 ml) and diethyl ether (100 ml). The organics were washed with bring (30 ml), dried (Na_2SO_4) and evaporated in vacuo to give an oil. The oil was purified by flash chromatography (SiO_2:hexane/ethyl acetate (85:15)) to afford the title compound as a colorless oil (362 mg).
R_f (SiO_2; ethyl acetate.hexane (1:4) 0.26 and 0.22 mixture of isomers.

E. 4-[1-(3-Cyclopentyloxy-4-methoxyphenyl)ethyl]-5-methyl-pyrazol-3-one

To a stirred solution of methyl 2-acetyl-3-(3-cyclopentyloxy-4-methoxyphenyl)-butanoate (362 mg, 1.08 mmol) in absolute ethanol (10 ml) at 0°C was added hydrazine monohydrate (54 mg, 1.08 mmol) in one portion. The resulting solution was stirred at 0°C for 45 minutes and then refluxed at 80°C for 3 hours. Further hydrazine monohydrate (15.6 mg, 3.1 x 10^{-4} mol) was added and refluxing continued for a further 3 hours. After cooling to room temperature, the reaction mixture was concentrated in vacuo and purified by flash chromatography (SiO_2; methylene chloride/ethanol/ammonia (97.5:2.5:0.25)) to afford the title compound as a white solid (76 mg).
^{1}H ($CDCl_3$; 250 MHz) δ 6.80 (m, 3H), 4.72 (m, 1H), 3.93 (q, 1H), 3.79 (s, 3H), 2.00 (s, 3H), 183 (m, 6H), 1.60 (d, 3H), 1.57 (m, 2H).

EXAMPLE 11

5-(3-Cyclopentyloxy -4-methoxybenzal)hydantoin

A solution of 3-(3-cyclopentyloxy-4-methoxybenzal)hydantoin (1 g, 3.30 mmol) in ethanol/methylene chloride ((3:1) 50 ml) containing palladium on activated carbon (5% Pd, 200 mg) was hydrogenated at 40 p.s.i. for 6 hours at room temperature. The mixture was filtered through celite and the filter cake washed with methylene chloride (2 x 40 ml). The filtrate was concentrated in vacuo and purified by flash chromatography (SiO_2; methylene chloride/ethanol/ammonia (96:4:0.4)) to afford the title compound as a white solid (578 mg). m.p. 151-153°C.

^1H NMR ($CDCl_3$; 250 MHz) δ 8.41 (brs, 1H), 6.74 (m, 3H), 5.79 (brs, 1H), 4.73 (brs, 1H), 4.24 (dd, 1H), 3.80 (s, 3H), 2.98 (AB system 2 x dd, 2H), 1.83 (m, 6H), 1.59 (m, 2H).

EXAMPLE 12

Ethyl 3-(3-cyclopentyloxy-4-methyoxybenzylamino)pyrazole-4-carboxylate

A solution of ethyl 3-aminopyrazole 4-carboxylate (70 g, 0.45 mol) and 3-cyclopentyloxy-4-methoxybenzaldehyde (100 g, 0.45 mol) in methanol (400 mL) was treated with sodium cyanoborohydride (19.0 g, 0.30 mol) and sodium acetate (2.0 g, 0.024 mol) in a stirred reaction vessel equipped with pH stat attached to a syringe pump and a syringe filled with 3 N acetic acid in methanol. The pH stat was set to maintain pH 7. The acetic acid solution was added as the reaction proceeded. After 24 hours, 169 mL of acetic acid solution had been added and no aldehyde remained in the reaction mixture by TLC (silica gel, 10% methanol/methylene chloride) and 3-

cyclopentyloxy-4-methoxy-benzaldehyde (19.0 g, 0.086 mol) was added to the reaction mixture. After 30 hours, a total of 216 mL of acetic acid solution had been added and 3-cyclopentyloxy-4-methoxybenzaldehyde (16 g, 0.072 mol) was added to the reaction mixture. After 48 hours, 263 mL of acetic acid solution had been added and additional 3-cyclopentyloxy-3-methoxybenzaldehyde (29 g, 0.13 mol) was added to the reaction mixture. After 76 hours, 320 mL of acetic acid solution had been consumed and the reaction mixture was evaporated under reduced pressure. The residue was partitioned between water (400 mL) and ethyl acetate (400 mL) and the ethyl acetate was evaporated under reduced pressure to give 240 g of crude product. The crude product was purified by flash chromatography over 900 g of flash chromatography silica gel and eluted with methanol-methylene chloride mixtures. Elution with pure methylene chloride afforded by-product 3-cyclopentyloxy-4-methoxybenzyl alcohol. Elution with 1-25% methanol-methylene chloride gave 91 g (42%) of nearly pure ethyl 3-(3-cyclopentyloxy-4-methoxybenzyl-amino)pyrazole-4-carboxylate. A portion of this ethyl 3-(3-cyclopentyloxy-4-methoxybenzylamino)pyrazole carboxylate (29 g) was recrystallized from methyl t-butyl ether to give 16.8 g of pure ethyl 3-(3-cyclopentyloxy-4-methoxybenzyl-amino)pyrazole-4-carboxylate, mp 102-104°.

EXAMPLE 13

3-(3-cyclopentyloxy-4-methoxy-benzylamino)-4-cyanopyrazole

A solution of 3-amino-4-cyanopyrazole (5.0 g, 0.16 mol), 3- cyclopentyloxy-4-methoxybenzaldehyde (10.0 g, 0.045 mol) and sodium acetate (0.2 g, 2.4 mol) in methanol (70 mL) was placed in a stirred reaction flask equipped with a pH stat controlling a syringe pump and syringe filled with 3 N acetic acid in methanol. The pH

stat was set to maintain pH 7. After 24 hours, more 3-cyclopentyloxy-4-methoxybenzaldehyde (7.0 g, 0.031 mol) was added and the reaction was continued. After 48 hours, more 3-cyclopentyloxy-4-methoxybenzaldehyde (4.0 g, 9.0 mmol) and soduim cyanoborohydride (0.5 g, 7.9 mmol) was added and the reaction was continued. After 72 hours, more sodium cyanoborohydride (0.5 g, 7.9 mmol) was added and after 96 hours, the reaction was stopped and the solvent was removed under reduced pressure. The residue was partitioned between ethyl acetate (75mL) and water (50 mL). The ethyl acetate layer was washed with water (2 x 50 mL) and evaporated. The crude product was chromaotgraphed over 200 g of flash chromatography silica gel. Elution with 2% methanol/methylene chloride removed some impurities including 3-cyclopentyloxy-4-methoxybenzyl alcohol. Continued elution with methanol/methylene chloride mixtures of increasing methanol concentration afforded 8 g (56%) of nearly pure title compound. Pure 3-(3-cyclopentyloxy-4-methoxy-benzylamino)-4-cyanopyrazole, mp 159-160° was obtained by recrystallization from methanol.

EXAMPLE 14

3-(3-cyclopentyloxy-4-methoxy-benzylamino)-4-methylpyrazole

A stirred solution of ethyl 3-(3-cyclopentyloxy-4-methoxybenzylamino-pyrazole-4-carboxylate) (from EXAMPLE 12) (5.4 g, 0.015 mol) in THF (50 mL) at 0° was treated with sodium bis (2-methoxyethoxy)aluminum hydride (0.03 mole), 9 mL of 3.4 M solution in toluene. After 3 hours, another 9 mL portion of the sodium bis (2-methoxy-ethoxy)aluminum hydride solution (0.03 mol) was added. The reaction was stirred overnight at room temperature and methanol (20 mL) was added. The reaction mixture was diluted with water and extracted with ethyl acetate. The

ethyl acetate extracts were washed with water and evaporated under reduced pressure. The residue crystallized upon trituration with hexanes. Pure title compound (1.7 g, 38%), mp 76-77°, was obtained after two crystallizations from methyl t-butylether.

EXAMPLE 15

3-(3-cyclopentyloxy-4-methoxy-benzylamino)-4-methoxymethylpyrazole

A solution of 3-(3-cyclopentyloxy-4-methoxybenzylamino)-4-hydroxymethylpyrazole (1.0 g, 3.15 mmol) and p-toluenesulfonic acid monohydrate (0.2 g, 1.0 mmol) in methanol (100 mL) was kept at room temperature for 10 min. The reaction mixture was neutralized with 1 N aqueous sodium hydroxide and evaporated under reduced pressure at room temperature. The residue was partitioned between water (50 mL) and ethyl acetate (50 mL). The layers were separated and the aqueous layer was extracted with ethyl acetate (10 mL). The combined ethyl acetate layers were washed with water and evaporated under reduced pressure. The residue was taken up in a small volume of methylene chloride and applied to a 4 mm silica gel disk on a Chromatotron. Elution with 525 mL of methylene chloride and 275 mL of 1% methanol/methylene chloride removed some impure material. Continued elution with 75 mL of 1% methanol/methylene chloride afforded 380 mg (36%) of pure 3-(3-cyclopentyloxy-4-methoxybenzylamino)-4-methyoxymethylpurazole, mp. 112-115°.

EXAMPLE 16

ethyl 3-(3-cyclopentyloxy-4-methoxy phenyl-1-ethen-2-yl)pyrazole-4-carboxylate

A four-step process as set forth below was used to prepare the title compound.

A: Ethyl 5-(3-cyclopentyloxy-4-methoxyphenyl)-3-oxo-5-hydroxypentanoate

Sodium hydride (6.0 g of 60% sodium hydride in mineral oil, 0.15 mol) was placed in a 3-neck flask equiped with a mechanical stirrer under nitrogen and washed twice with hexanes. THF (200 mL) was added and the mixture was cooled in an ice bath. Ethyl acetoacetate (17.6 g, 0.135 mol) was added dropwise and the mixture was stirred for 10 minutes after the addition. Butyllithium (0.35 mol, 84 mL of 1.6 M solution in hexanes) was added dropwise to give an orange solution. A solution of 3-cyclopentyloxy-4-methoxybenzaldehyde (29.6 g, 0.135 mol) in THF (100 mL) was added dropwise. After 10 minutes, the cold solution was treated with concentrated hydrochloric acid (26 mL, 0.29 mol), water (65 mL) and ether (500 mL). The ether layer was separated and washed with saturated brine (3 x 300 mL). The ether was evaporated to give 46.5 g of crude title compound. The crude product was dissolved in a small amount of 30% methylene chloride/hexanes and purified by chromatography over 400 g of flash chromatography silica gel. Elution with methylene chloride/hexane mixtures removed 9 g of starting aldehyde. Elution with 1% methanol/methylene chloride afforded the ethyl 5-(3-cyclopentyloxy-4-methoxyphenyl)-3-oxo-5-hydroxypentanoate (25.0 g, 53%) as an oil.

B. Ethyl 5-(3-cyclopentyloxy-4-methoxyphenyl)-3-oxo-4-pentenoate

To a solution of p-toluenesulfonic acid monohydrate (0.13 g, 0.68 mmol) warmed on the steam bath was added ethyl 5-(3-cyclopentyloxy-4-methoxy)-3-oxo-5-hydroxypentanoate (13.5 g, 0.039 mol). After 5 minutes, the solution was cooled and purified by chromatography over flash chromatography silica gel (130 g). Elution

with methylene chloride/hexane mixtures gave 3.5 g (27%) of pure ethyl 5-(3-cyclopentyloxy-4-methoxyphenyl)-3-oxo-4-pentenoate.

C. Ethyl 5-(3-cyclopentyloxy-4-methoxyphenyl)-3-oxo-2-ethyoxymethylene-4-pentenoate

A solution of ethyl 5-(3-cyclopentyloxy-4-methoxyphenyl) 3-oxo-4-pentenoate (2.2 g, 6.8 mmol) and diethoxymethyl acetate (1.1 g, 6.8 mmol) was heated at 160° for 1 hour. The reaction mixture was taken up in methylene chloride and washed with saturated sodium bicarbonate solution. The methylene chloride was evaporated under reduced pressure and the residue was purified by flash chromatography over 15 g of flash chromatography silica gel. Elution with methylene chloride/hexane mixtures removed some starting material and by-products. Elution with pure methylene chloride afforded 1.1 g (42%) of ethyl 5-(3-cyclopentyloxy-4-methoxyphenyl)-3-oxo-2-ethoxymethylene-4-pentenoate.

D. Ethyl 3-(3-cyclopentyloxy-4-methoxyphenyl-ethyl-2-yl)pyrazole-4-carboxylate

A solution of ethyl 5-(3-cyclopentyloxy-4-methoxyphenyl)-3-oxo-2-ethoxymethylene-4-pentenoate (1.1 g, 2.6 mmol) in ethanol (10 mL) was treated with anhydrous hydrazine (0.1 g, 3.1 mmol). After standing overnight, the solvent was removed under reduced pressure and the residue was purified by flash chromatography over 10 g of flash chromatography silica gel. Elution with methylene chloride afforded the ethyl 3-(3-cyclopentyloxy-4-methoxyphenyl-ethyl-2-yl)pyrazole-4-carboxylate (0.5 g, 54%). Pure title compound mp 97-100° was obtained by crystallization from ether/hexanes.

EXAMPLE 17

3-(3-cyclopentyloxy-4-methoxy-phenyl-1-ethen-2-yl) pyrazole-4-methanol

A solution of ethyl 3-(3-cyclopentyloxy-4-methoxyphenyl-1-ethen-2-yl)pyrazole-4-carboxylate (from Example 16), (0.5 g, 1.4 mmol) in THF (50 mL) was stirred overnight with lithium aluminum hydride (0.16 g, 2.1 mmol). The reaction mixture was then treated successively with water, (0.5 mL), 15% aqueous sodium hydroxide (0.5 mL) and water (1.5 mL). The inorganic material was filtered and washed with methylene chloride. The ether and methylene chloride solutions were combined and washed with water and evaporated. The crude product was dissolved in methylene chloride and purified by flash chromatography over 4.5 g of flash chromatography silica gel. Elution with methylene chloride/methanol mixtures afforded 3-(3-cyclopentyloxy-4-methoxyphenyl-1-ethen-2-yl)pyrazole-4-carbinol (0.30 g, 68%). Pure title compound, mp 121-123°, was obtained by crystallization from toluene.

EXAMPLE 18

ethyl 3-[2-(3-cyclopentyloxy-4-methoxyphenyl)ethyl]pyrazole-4-carboxylate

A solution of ethyl 3-(3-cyclopentyloxy-4-methoxyphenyl-1-ethylene-2-yl)pyrazole-4-carboxylate (Example 16), (1.1 g, 3.1 mmol) in ethyl acetate (50 mL) was hydrogenated at 20 psi over 0.5 g of 10% Pd on carbon catalyst. After 24 hours, the catalyst as filtered and the solution was hydrogenated again with 0.5 g of fresh 10% Pd on carbon catalyst. After hydrogen uptake ceased,the catalyst was filtered and the crude product was purified by flash chromatography over 20 g of flash chromatography silica gel. Elution with methylene chloride and 0.25% ethanol/methylene chloride removed

some impurities. Elution with 2% ethanol/methylene chloride afforded ethyl 3-[2-(3-cyclopentyl-oxy-4-methoxyphenyl)ethyl]pryazole-4-carboxylate (0.70 g, 63%) Pure title compound, mp 80-82° was obtained by crystallization from ether/hexanes.

EXAMPLE 19

3-[2-(3-Cyclopentyloxy-4-methoxyphenyl)ethyl]pyrazole-4-methanol

A solution of ethyl 3-[2-(3-cyclopentyloxy-4-methoxyphenyl) ethyl]pyrazole-4-carboxylate (from Example 18), (0.40 g, 1.1 mmol) was stirred overnight with lithium aluminum hydride (0.18 g, 4.7 mmol). THF (25 mL) was added and stirring was continued for 1 hour. The reaction mixture was then treated successively with water (0.2 mL), 15% aqueous sodium hydroxide (0.2 mL) and water (0.6 mL). The inorganic material was filtered and washed and methylene chloride. The organic solutions were combined and evaporated under reduced pressure. The crude product was purified by flash chromatography over 3.5 g of flash chromatography silica gel. Elution with methylene chloride and 1% methanol/methylene chloride removed some impurities. Elution with 2% methanol/methylene chloride gave 0.21 g (60%) of 3-[2-(3-cyclopentyloxy-4-methoxyphenyl)ethyl]pyrazole carbinol. Pure title compound, mp 88-91°, was obtained by crystallization from ether/hexanes.

Example 20

2-(3-Cyclopentyloxy-4-methoxyphenyl)-4-trifluoromethyl-imidazole

1,1-Dibromo-3,3,3-trifluoroacetone (2.95 g, 1.64 ml, 10.9 mmol) was added to a solution of NaOAc (1.52 g, 18 mmol) in water (8 ml). The solution was heated at 80°C for 45 min. To the cooled solution at 0°C was added 3-cyclopentyloxy-4-methoxybenzaldehyde (2 g, 9.07 mmol) and

methanol (34 ml), followed by concentrated NH_4OH (11 ml). A homogeneous reaction mixture was obtained, which was stirred overnight at room temperature. Volatiles were removed *in vacuo* and flash chromatography (SiO_2; EtOAc:hexane (3:7)) produced 2-(3-cyclopentyloxy-4-methoxyphenyl)-4-trifluoromethyl imidazole (1.728 g, 58%) as a white solid, mp 157-159°C.

δ_H (250MHz;$CDCl_3$) 1.45-1.9 (8H,m,4 x CH_2), 3.85 (3H,s,OMe), 4.7 (1H,m,CH), 6.8 (1H,d,ArH), 7.3 (1H,d,ArH), 7.4 (2H,m,ArH), 10.3 (1H,s,NH)

Example 21

2-(3-Cyclopentyloxy-4-methoxyphenyl)-imidazole-4-carboxylic acid

2-(3-cyclopentyloxy-4-methoxyphenyl)-4-trifluoromethyl imidazole (688 mg, 2.11 mmol) and 1N NaOH (25 ml) were heated at 90°C for 2 h. Afterwhich time the reaction was made acidic by addition of c.HCl, the precipitate was collected by filtration and the filter was washed with ethanol (5 ml) and ether (5 x 20 ml), dried *in vacuo*, to afford 2-(3-cyclopentyloxy-4-methoxyphenyl)-imidazole-4-carboxylic acid (356 mg, 56%) as a light tan solid, mp 206-208°C.

δ_H (250MHz;d_4,MeOH) 1.7 (2H,m,CH_2), 1.8-2.0 (6H,m,3 x CH_2), 3.9 (3H,s,OMe), 4.9 (1H,m,CH), 7.1 (1H,d,ArH), 7.6 (2H,m,ArH), 8.0 (1H,s,ArH).

Example 22

2-(3-Cyclopentyloxy-4-methoxyphenyl)-imidazole-4-formamide

A: 2-(3-Cyclopentyloxy-4-methoxyphenyl)-4-cyanoimidazole

A mixture of 2-(3-cyclopentyloxy-4-methoxyphenyl)-4-trifluoromethyl-imidazole (1.04 g, 3.18 mmol) and 5% aqueous ammonium hydroxide (300 ml) was heated to reflux for 24 hours. The reaction mixture was cooled and carefully neutralised with acetic acid. The mixture was

extracted with methylene chloride (3 x 150 ml) and the volatiles removed *in vacuo* to afford the crude product. Flash chromatography (SiO_2; EtOAc:hexane (2:3)) produced the 2-(3-cyclopentyloxy-4-methoxyphenyl)-4-cyanoimidazole (320 mg, 35%) as a pale yellow solid.

B: <u>2-(3-Hydroxy-4-methoxyphenyl)-4-imidazole-4-formamide</u>

A mixture of the 2-(3-Cyclopentyloxy-4-methoxyphenyl)-4-cyanoimidazole (320 mg, 1.18 mmol) and c.HCl (25 ml) was heated to 50°C overnight. The reaction was then cooled to 0°C, neutralised with c.NH_4OH and extracted with ethyl acetate (5 x 80 ml), the combined organics were dried over Na_2SO_4 and the volatiles removed *in vacuo*. Flash chromatography (SiO_2;CH_2Cl_2 to CH_2Cl_2:EtOH (7:3) (1% NH_3)) afforded 2-(3-hydroxy-4-methoxyphenyl)-imidazole-4-formamide (110 mg, 40%) as a white solid.

C: <u>2-(3-Cyclopentyloxy-4-methoxyphenyl)-imidazole-4-formamide</u>

A mixture of 2-(3-hydroxy-4-methoxyphenyl)-imidazole-4-formamide (110 mg, 0.47 mmol), cyclopentyl bromide (60 μl, 0.56 mmol) and K_2CO_3 (162 mg, 1.2 mmol) in DMF (10 ml) were heated at 70°C overnight. A further quantity of cyclopentyl bromide (60 μl, 0.56 mmol) and K_2CO_3 (162 mg, 1.2 mmol) were added and the reaction mixture was cooled to room temperature, diluted with water (50 ml), extracted with ethyl acetate (2 x 100 ml). The combined organics were washed with brine (30 ml) dried over Na_2SO_4 and the volatiles removed *in vacuo*. Flash chromatography (SiO_2; CH_2Cl_2:EtOH (9:1) (1% NH_3)) afforded 2-(3-cyclopentyloxy-4-methoxyphenyl)-imidazole-4-formamide (43 mg,) as a white solid, mp d.>195°C.

δ_H (250MHz;d_4,MeOH) 1.65 (2H,m,CH_2), 1.7-2.0 (6H,m,3 x CH_2), 3.9 (3H,s,OMe), 7.0 (1H,d,ArH), 7.5 (2H,m,ArH), 7.7 (1H,s,ArH).

Example 23

2-(3-Cyclopentyloxy-4-methoxyphenyl)-imidazole-4-carboxylic acid-2,-6-dimethylphenyl amide

A mixture of 2-(3-cyclopentyloxy-4-methoxyphenyl)-imidazole-4-carboxylic acid (400 mg, 1.32 mmol) and $SOCl_2$ (10 ml) containing DMF (1 drop) was heated to reflux for 2 hours. The volatiles were removed *in vacuo* and to the residue was added toluene (25 ml) and the solvent evaporated. This procedure was repeated to remove dissolved gaseous by-products. The residue was dissolved in THF (10 ml) and added dropwise at 0°C over 10 minutes, to a solution of the salt of 2,6-dimethylaniline (510 µl, 4.14 mmol) in THF (30 ml) (formed by adding a solution of the aniline in THF (15 ml) to a suspension of NaH (167 mg, 4.14 mmol) is THF (15 ml) at room temperature). The resultant solution was stirred at room temperature for 48 hours, diluted with 1N HCl (20 ml) and the mixture extracted with methylene chloride (2 x 50 ml). The combined organics were dried over Na_2SO_4 and the volatiles removed *in vacuo*. Flash chromatography (SiO_2; CH_2Cl_2:EtOH (97:3)) afforded 2-(3-cyclopentyloxy-4-methoxyphenyl)-imidazole-4-carboxylic acid-2,6-dimethylphenyl amide (80 mg, 15%) as a pale yellow solid, mp 118-122°C.

δ_H (250MHz;$CDCl_3$) 1.6 (2H,m,CH_2), 1.7-2.0 (6H,m,3 x CH_2), 2.3 (6H,s,2 x Me), 3.9 (3H,s,OMe), 5.0 (1H,m,CH), 6.8 (1H,d,ArH), 7.1 (2H,d,ArH), 7.8-8.0 (3H,m,ArH), 8.5 (1H,6s,NH), 10.3 (1H,6s,NH).

Example 24

2-(3-Cyclopentyloxy-4-methoxyphenyl)-imidazole-4-methanol

A: 2-(3-Cyclopentyloxy-4-methoxyphenyl)-imidazole-4-methylcarboxylate

To a solution of 2-(3-cyclopentyloxy-4-methoxyphenyl)-imidazole-4-carboxylic acid (0.5 g, 1.65 mmol) in dry methanol (2 ml) at 0°C was added acetyl chloride (0.8 ml, 11.2 mmol). The reaction mixture was stirred at room temperature for 4 days and then the volatiles were removed *in vacuo*. The oily residue was dissolved in water (20 ml), basified with 1N NaOH and extracted with methylene chloride (3 x 50 ml). The combined organics were dried over Na_2SO_4 and the volatiles removed *in vacuo*. Flash chromatography (SiO_2; EtOAc:Hexane (4:1)) afforded 2-(3-cyclopentyloxy-4-methoxyphenyl)-imidazole-4-methyl carboxylate (225 mg, 43%), as a white solid, mp 165-168°C.

B: <u>2-(3-Cyclopentyloxy-4-methoxyphenyl)-imidazole-4-methanol</u>

To a solution of 2-(3-cyclopentyloxy-4-methoxyphenyl)-imidazole-4-methylcarboxylate (225 mg, 0.71 mmol) in dry THF (15 ml) was added, with stirring at -40°C, a solution of diisobutylaluminium hydride (1M in THF, 6.0 ml, 60 mmol). After 1.5 hours the reaction mixture was poured onto saturated NH_4Cl (50 ml) and extracted with ethyl acetate (3 x 100 ml). The combined organics were washed with saturated NH_4Cl (50 ml), dried over Na_2SO_4 and the volatiles removed *in vacuo*. Flash chromatography (SiO_2; CH_2Cl_2:EtOH (95:5) (1% NH_3)) afforded 2(3-cyclopentyloxy-4-methoxyphenyl)-imidazole-4-methanol (88 mg, 45%) as a white solid, mp 188-190°C.

δ_H (250MHz;$CDCl_3$) 1.5 (2H,m,CH_2), 1.6-1.9 (6H,m,3 x CH_2), 3.7 (3H,s,OMe), 4.5 (2H,s,CH_2O), 4.7 (1H,,m,CH), 6.7 (1H,d,ArH), 6.8 (1H,s,ArH), 7.3 (1H,dd,ArH), 7.4 (1H,d,ArH).

Example 25

2-(3-Cyclopentyloxy-4-methoxyphenyl)-imidazole-4-carboxylic acid, N-(2-hydroxyethyl) amide

To a solution of 2-(3-Cyclopentyloxy-4-methoxyphenyl)-imidazole-4-carboxylic acid (500 mg, 1.65 mmol) in DMF (15 ml) at room temperature was added carbonyldiimidazole (295 mg, 1.8 mmol). The resultant solution was stirred for 30 minutes and then ethanolamine (180 μl, 1.8 mmol) was added and the reaction mixture stirred at room temperature overnight. Water (75 ml) was added and the mixture extracted with ethyl acetate (2 x 75 ml). The combined organics were washed with brine (40 ml), dried over Na_2SO_4 and the volatiles removed *in vacuo*. Flash chromatography (SiO_2; CH_2Cl_2:EtOH (95:5) (1% NH_3)) afforded 2-(3-cyclopentyloxy-4-methoxyphenyl)-imidazole-4-carboxylic acid, N-(2-hydroxyethyl) amide (247 mg, 43%) as a white solid, mp 206-208°C.

δ_H (250MHz;d_6,DMSO) 1.6 (2H,m,CH_2), 1.65 (4H,m,CH_2), 1.9 (2H,m,CH_2), 3.3 (2H,m,NCH_2), 3.3 (1H,s,NH), 3.5 (2H,m,OCH_2), 3.8 (3H,s,OMe), 4.8 (1H,m,CH), 4.8 (1H,s,OH), 7.0 (1H,d,ArH), 7.5 (1H,d,ArH), 7.7 (1H,s,ArH), 7.85 (1H,t,ArH), 12.8 (1H,6s,NH).

Example 26

4-(1-(3-Cyclopentyloxy-4-methoxyphenyl)-2-phenyl-ethyl)-5-methyl-pyrazol-3-one

A: Ethyl-3(3-Cyclopentyloxy-4-methoxyphenyl)-2-acetyl-prop-2-enoate

A mixture of 3-Cyclopentyloxy-4-methoxybenzaldehyde (7 g, 31.8 mmol), ethyl acetoacetate (4.13 g, 31.8 mmol), piperidine (275 mg, 3.18 mmol) and glacial acetic acid (100 mg) in toluene (350 ml) was heated at reflux with a Dean-Stark trap for 2 days, during which time, at regular intervals, further additions of piperidine (4 x 275 mg) and glacial acetic acid (4 x 100 mg) were made. The

reaction mixture was then diluted with water and extracted with methylene chloride (3 x 150 ml), dried over Na_2SO_4 and the volatiles removed *in vacuo*. Flash chromatography (SiO_2; EtOAc:hexane (1:9)) afforded ethyl-3-(3-cyclopentyloxy-4-methoxyphenyl)-2-acetyl-prop-2-enoate (2 g, 19%) as a yellow oil.

B: Ethyl-3-(3-Cyclopentyloxy-4-methoxyphenyl)-2-acetyl-4-phenyl-butanoate

Cuprous iodide (1.15 g, 6.05 mmol) in dry THF (10 ml) was treated at 0°C with benzylmagnesium bromide (2 M in THF, 6.05 ml, 12.1 mmol) over a 3 minute period. The cuprate was stirred at 0°C for 30 minutes and then cooled to -78°C and then TMSCl (3.28 g, 30.2 mmol) in THF (5 ml) was added dropwise keeping the reaction temperature below -60°C. The mixture was stirred at below -60°C for a further 10 minutes and then ethyl-3-(3-cyclopentyloxy-4-methoxyphenyl)-2-acetyl-prop-2-enoate (1 g, 3.01 mmol) in THF (5 ml) was added dropwise over 3 minutes. The mixture was stirred at below -60°C for 45 minutes and then saturated NH_4Cl (30 ml) and water (20 ml) were added. The mixture was allowed to warm to room temperature, the resultant precipitate was removed by filtration and the filtrate evaporated, the residue was dissolved in methylene chloride (200 ml), washed with water (30 ml), 1n HCl (50 ml) and water (30 ml), dried over Na_2SO_4 and the volatiles removed *in vacuo*. Flash chromatography (SiO_2; EtOAc:hexane (1:9)) afforded ethyl-3-(3-cyclopentyloxy-4-methoxyphenyl)-2-acetyl-4-phenyl-butanoate (1.19 g), 92%) as a yellow oil.

C: 4-(1-(3-Cyclopentyloxy-4-methoxyphenyl))-2-phenyl-ethyl)-5-methyl-pyrazol-3-one

Hydrazine monohydrate (207 mg, 4.2 mmol) was added to a solution of 3-ethyl-(3-cyclopentyloxy-4-methoxyphenyl)-2-acetyl-4-phenyl-butanoate (1.186 g, 2.8

mmol) in methanol at 0°C. The resultant mixture was allowed to reach room temperature over 45 minutes and then heated to reflux overnight. The volatiles were removed *in vacuo* and flash chromatography (SiO_2; CH_2Cl_2:EtOH (95:5) (1% NH_3)) afforded 4-(1-(3-cyclopentyloxy-4-methoxyphenyl)-2-phenyl-ethyl)-5-methyl-pyrazol-3-one (460 mg, 42%) as a pale yellow solid, mp 88-90°C.

δ_H (250MHz;$CDCl_3$) 1.5 (2H,m,CH_2), 1.6-1.9 (6H,m,3 x CH_2), 1.9 (3H,s,Me), 3.2-3.5 (2H,m,ArCH_2), 3.8 (3H,s,OMe), 3.85 (1H,m,ArCH), 4.7 (1H,m,CH), 6.7 (1H,d,ArH), 6.85 (1H,dd,ArH), 7.0 (1H,d,ArH), 7.2 (5H,m,ArH).

EXAMPLE 27

Protocols for PDE IV, PDE III, and PDE V inhibition activity are set forth below:

Type III Phosphodiesterase
Enzyme Isolation Protocol

The Type III PDE is isolated from human platelets using a procedure similar to that previously described by Weishaar, R.E.; Burrows, S.D.; Kobylarg, D.C., Quade, N.M.; Evans, D.B., Biochem. Pharmacol., 35:787, 1986. Briefly, 1-2 units of platelets are suspended in an equal volume of buffer (20 mM Tris-HCl, pH 7.5, containing 2 mM magnesium acetate, 1 mM dithiothreitol, and 5 mM Na_2 EDTA). The proteinase inhibitor phenylmethyl-sulfonyl fluoride (PMSF) is also included in this buffer at a final concentration of 200 μM. The suspension is homogenized using a polytron and the homogenate centrifuged at 100,000 x g for 60 minutes. This and all subsequent procedures are performed at 0-4°C. The supernatant is then filtered through four layers of gauze and applied to a DEAE-Trisacryl M column, previously equilibrated with buffer B (20 mM Tris-HCl, pH 7.5, containing 1 mM magnesium acetate, 1 mM dithiothreitol

and 200 μM PMSF). After application of the sample, the column is washed with several bed volumes of buffer B, after which the different forms of PDE are eluted from the column using two successive linear NaCl gradients (0.05-0.15 M, 300 ml total; 0.15-0.40 M, 200 ml total). Five ml fractions are collected and assayed for cyclic AMP and cyclic GMP PDE activity. Fractions containing PDE III activity are pooled and dialyzed overnight against 4 L of buffer B. The dialyzed PDE III is then concentrated to 10% of the original volume, diluted to 50% with ethylene glycol monoethyl ether and stored at -20°C. PDE III can typically be retained for up to four weeks with little or no loss of activity.

Measuring Type III PDE Activity

Enzyme activity is assessed by measuring the hydrolysis of [^{3}H]-cyclic AMP, as described by Thompson, W.J., Teraski, W.L., Epstein, P.N., Strada, S.J.: Adv. Cyclic Nucleotide Res. 10:69, 1979. The cyclic AMP concentration used in this assay is 0.2 μM, which approximates to the K_m value. Protein concentration is adjusted to ensure that no more than 15% of the available substrate is hydrolyzed during the incubation period.

All test compounds are dissolved in dimethyl sulfoxide (final concentration of 2.5%). This concentration of dimethyl sulfoxide inhibits enzyme activity by approximately 10%.

Type IV Phosphodiesterase
Enzyme Isolation Protocol

The Type IV PDE is isolated from bovine tracheal smooth muscle using a procedure similar to that previously described by Silver, P.J., Hamel, L.T., Perrone, M.H. Bentley, R.G. Bushover, C.R., Evans, D.B.: Eur. J. Pharmacol. 150:85,1988.(1). Briefly, smooth muscle from bovine trachea is minced and homogenized

using a polytron in 10 volumes of an extraction buffer containing 10 mM Tris-acetate (pH 7.5), 2 mM magnesium chloride, 1 mM dithiothreitol and 2,000 units/ml of aprotinin. This and all subsequent procedures are performed at 0-4°C. The homogenate is sonicated and then centrifuged at 48,000 x g for 30 minutes. The resulting supernatant is applied to a DEAE Trisacryl M column previously equilibrated with sodium acetate and dithiothreitol. After applications of the sample, the column is washed with sodium acetate/dithiothreitol, after which the different forms of PDE are eluted from the column using a linear Tris-HCl/NaCl gradient. Fractions containing Type IV PDE are collected, dialyzed and concentrated to 14% of the original volume. The concentrated fractions are diluted to 50% with ethylene glycol and stored at -20°C.

<u>Measuring Type IV PDE Activity</u>

Enzyme activity is assessed by measuring the hydrolysis of [^{3}H]-cyclic AMP, as described by Thompson, W.J., Teraski, W.L., Epstein, P.N., Strada, S.J.: Adv. Cyclic Nucleotide Res. 10:69, 1979. The cyclic AMP concentration used in this assay is 0.2 μM, which approximates to the K_m value. Protein concentration is adjusted to ensure that no more than 15% of the available substrate is hydrolyzed during the incubation period.

All test compounds are dissolved in dimethyl sulfoxide (final concentration of 2.5%). This concentration of dimethyl sulfoxide inhibits enzyme activity by approximately 10%.

Type V Phosphodiesterase
<u>Enzyme Isolation Protocol</u>

<u>Enzyme Isolation Procedure</u>: The Type V PDE is isolated using a procedure similar to that previously described by Weishaar et al. (Weishaar, R.E., Kobylarz-

Singer, D.C., Keiser, J., Haleen, S.J., Major, T.C., Rapundalo, S., Peterson, J.T., Panek, R.: Hypertension 15:528, 1990). Briefly, 1-2 units of platelets are suspended in an equal volume of buffer A (20 mM Tris-HCl, pH 7.5, containing 2 mM magnesium acetate, 1 mM dithiothreitol, and 5 mM Na_2EDTA) using a polytron. The proteinase inhibitor phenylmethylsulfonyl fluoride (PMSF) are also included in this buffer at a final concentration of 200 uM. This and all subsequent procedures are performed at 0-4°C. The homogenate is then centrifuges at 100,000 xg for 60 minutes. The supernatant is then removed and filtered through four layers of gauze and applied to a DEAE-Trisacryl M column. The column is washed with several bed volumes of buffer B (20 mM Tris-HCl, pH 7.5, containing 2 mM magnesium acetate, 1 mM diothiothreitol, and 200 uM PMSF) and eluted by two successive linear NaCl gradients (0.05-0.15 M, 300 ml total; 0.15-0.40 M, 200 ml total). Five ml fractions are collected and assayed for cyclic AMP and cyclic GMP PDE activity. Fractions that contain PDE V are pooled and dialyzed overnight against 4 L of buffer C (20 mM Tris-HCl, pH 7.5, containing 2 mM magnesium acetate and proteinase inhibitors). The dialyzed PDE V is then concentrated to 10% of the original volume, diluted to 50% with ethylene glycol monoethyl ether and stored at -20°C. PDE V can typically be retained for up to four weeks with little or no loss of activity.

Measuring Type V PDE Activity: Enzyme activity are assessed by measuring the hydrolysis of $[^3H]$-cyclic GMP, as described by Thompson et al. (Thompson, W.J., Teraski, W.L., Epstein, P.N., Strada, S.J.: Adv. Cyclic Nucleotide Res. 10:69, 1979). The cyclic GMP concentration used in this assay is 0.2 uM, which approximates to the K_m value. Protein concentration is adjusted to ensure that no more

than 15% of the available substrate is hydrolyzed during the incubation period.

All test compounds are dissolved in dimethyl sulfoxide (final concentration of 2.5%). This concentration of dimethyl sulfoxide inhibits enzyme activity by approximately 10%. The reference Type V PDE inhibitor zaprinast is evaluated with each assay.

The compounds are tested over concentration range: 0.1, 1, 10, 100 uM (n=1), and I_{50} determinations are made using 5 appropriate concentrations (n=2).

EXAMPLE 28

Following the above procedures, the PDE III, PDE IV, PDE V inhibition for the compound of Example 1, 3-(3-cyclopentyloxy-4-methoxybenzylamino)-4-hydroxymethyl-pyrazole, and rolipram (PDE III, PDE IV) are tested and compared. The results are shown in Tables 1-3 below:

TABLE 1 - PDE III ACTIVITY

		% Inhibition			
Compound	Molecular Weight	1.0 μM	10 μM	100 μM	300 μM
Ex. 1	317.4	8%	22%	53%	precip-itate
Rolipram	--	--	7%	18%	35%

TABLE 2 - PDE IV ACTIVITY

	Molecular	% Inhibition				
Example	Mol. Wt.	0.001 μM	0.003. μM	0.01 μM	0.03 μM	0.1μM
Ex. 1	317.4	10%	26%	42%	58%	70%

Example	1.0 μM	10 μM
Rolipram	36%	67%

TABLE 3 - PDE V ACTIVITY

Compound	Molecular Weight	PDE V - % Inhibition 0.1 µM	1 µM	10 µM	100 µM
Example 1	317.40	0	0	4	30#

The concentration of Example 1 which yielded 50% inhibition of PDE IV (IC_{50}) was 0.016 µM.

The concentration of rolipram which yielded 50% inhibition of PDE IV (IC_{50}) in this same assay was 4.5 µM.

EXAMPLE 29

In this Example, the compounds prepared in the above examples were prepared as set forth above and tested for Type III and Type IV PDE Activity in similar fashion as set forth with regard to the procedures set forth in Example 20. The results are set forth in Table 4 below:

TABLE 4 - ACTIVITIES

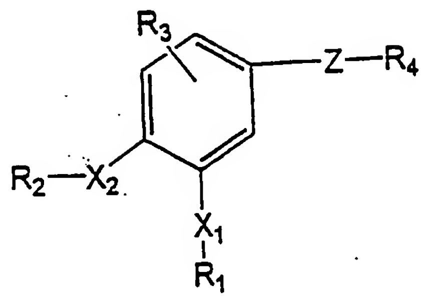
EXAMPLE	PDE IV IC_{50} (μM)	PDE III IC_{50} (μM)
1	0.016	>100
2	53	>300
3	109	>300
4	4.4	>300
5	15	>100
6	20% @ 100μM	>100
7	19% @ 100μM	>100
8	25	46
9	13	>100
10	7.8	>300
11	78	>300
12	3.593	85.317
13	22.80	>100
14	7.30	>300
15	0.17	>300
16	1.47	7.320
17	8.00	>100
18	12.50	>100
19	17.508	>300
20	14.68	>100
21	7.44	>250
22	3.9	76
23	7.28	>200
24	17.54	>300
25	4.48	>250
26	2.80	>100

As can be seen from the foregoing, the inventive compounds provide high levels of PDE-IV inhibition while at the same time relatively low levels of PDE-III inhibition.

While the invention has been illustrated with respect to the production and use of a particular compound, it is apparent that variations and modifications of the invention can be made without departing from the spirit or scope of the invention.

WHAT IS CLAIMED IS:

1. A compound of the formula:



wherein:

X_1 and X_2 may be the same or different and each is O or S;

R_1 and R_2 may be the same or different and each are saturated or unsaturated straight-chain or branched alkyl groups containing from 1 to 12 carbon atoms, cycloalkyl and cycloalkyl-alkyl groups containing from 3 to 10 carbon atoms in the cycloalkyl moiety; or one of R_1 and R_2 are hydrogen and the other represents a hydrocarbon group as set forth above;

R_3 is hydrogen, halogen, or a saturated or unsaturated straight-chain or branched alkyl group containing from 1 to 12 carbon atoms, a cycloalkyl and cycloalkyl-alkyl groups containing from 3 to 7 carbon atoms in the cycloalkyl moiety;

Z is a linkage selected from a bond, -NH-, $-CH_2O-$, $-CH_2CH_2-$, $-CH_2NH-$, $CH_2N(Me)$, $NHCH_2-$, $-CH_2CONH-$, $-NHCH_2CO-$, $-CH_2CO-$, $-COCH_2-$, $-CH_2COCH_2-$, $-CH(CH_3)-$, -CH=, and -HC=CH-, wherein the carbon and/or nitrogen atoms are unsubstituted or substituted with a lower alkyl, halogen, hydroxy or alkoxy group;

R_4 is a 5-membered heterocyclic group selected from the group consisting of a pyrazole, an imidazole, an oxazole, an oxadiazole, thiadiazole, thiazoyl, and a triazole, which is unsubstituted or substituted with one

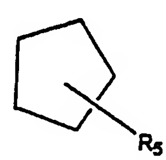
or more halogen atoms, C_{1-4} alkyl groups, hydroxyl groups, cyano groups, nitro groups, carboxyl groups, C_{1-4} alkyl esters, alkoxy groups, alkoxycarbonyl, amido, carboxamido, substituted or unsubstituted amino groups, cycloalkyl and cycloalkyl-alkyl groups containing from 3 to 10 carbon atoms in the cycloalkyl moiety, aryl or aralkyl groups preferably containing from about 6 to about 10 carbon atoms, or heterocyclic groups containing nitrogen, oxygen or sulfur in the ring; said alkyl, cycloalkyl, cycloalkyl-alkyl, aryl, and aryl-alkyl groups being unsubstituted or substituted by halogen atoms, hydroxyl groups, cyano groups, carboxyl groups, C_{1-4} alkoxy groups, alkoxycarbonyl, carboxamido or substituted or unsubstituted amino groups, or one or more lower alkyl groups having from 1 to 3 carbon atoms, with the proviso that when R_4 is other than 4-imidazolinone or 4-pyrolidinone.

2. The compound of claim 1 wherein R_1 is alkyl of 1-12 carbon atoms or cycloalkyl of 3-6 carbon atoms, which cycloalkyl may be substituted by one or more alkyl groups or by one or more halogens, R_2 is hydrogen, or alkyl of 1-12 carbon atoms, and wherein R_3 is hydrogen, lower alkyl or halogen.

3. The compound of claim 2 wherein R_2 is lower alkyl.

4. The compound of claim 3 wherein R_1 is cycloalkyl optionally substituted by one or more halogens.

5. The compound of claim 1 wherein R_2 is methyl or ethyl and wherein R_1 is cyclopentyl optionally substituted by R_5 as shown in the following structural formula:



wherein R_5 is hydrogen or a saturated or unsaturated straight-chain lower alkyl group containing from about 1 to about 6 carbon atoms, unsubstituted or substituted with one or more halogen atoms, hydroxyl groups, cyano groups, nitro groups, carboxyl groups, alkoxy groups, alkoxycarbonyl, carboxamido or substituted or unsubstituted amino groups.

6. The compound of claim 2 wherein Z is a linkage selected from $-CH_2CH_2-$, $-CH_2NH-$, $CH_2N(Me)$, $-NHCH_2-$, $-CH_2CONH-$, and $-NHCH_2CO-$.

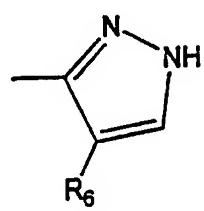
7. The compound of claim 2, wherein X_1 and X_2 are O.

8. The compound of claim 6 wherein R_4 is an unsubstituted or substituted pyrazole.

9. The compound of claim 6 wherein R_4 is a substituted or unsubstituted imidazole group.

10. The compound of claim 6 wherein R_4 is a substituted or unsubstituted triazole group.

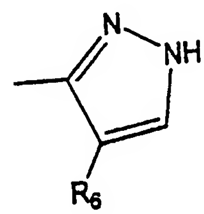
11. The compound of claim 6 wherein R_4 is a substituted pyrazole having the following structure:



wherein R_6 is a lower alkyl having from about 1 to about 3 carbon atoms.

12. The compound of claim 6 wherein Z is $-CH_2NH-$.

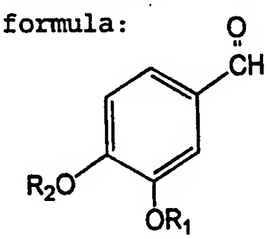
13. The compound of claim 6 wherein Z is $-CH_2NH-$ and R_4 is a substituted pyrazole having the following structure:



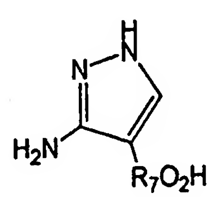
wherein R_6 is a lower alkyl having from about 1 to about 3 carbon atoms.

14. The compound of claim 1, selected from the group consisting of 3-(3-cyclopentyloxy-4-methoxybenzylamino)-4-hydroxymethyl pyrazole; and 3-(3-cyclopentyloxy-4-methoxybenzylamino)-4-methoxymethylpyrazole.

15. A method of producing the compound of claim 1 which comprises condensing a 3-cyclopentyloxy-benzaldehyde of the formula:

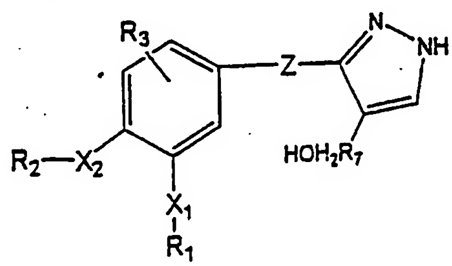


with a 3-amino-4-pyrazole carboxylic acid of the formula:



in the presence of sodium cyanoborohydride to produce the corresponding 3-(3-cyclopentyloxy-4-benzylamino)-4-pyrazolecarboxylic acid, and treating the same with excess boraine-tetrahydrofurane complex to form the compound of claim 1, wherein R, R_1 and R_2 have the same definitions as in claim 1.

16. A compound of the formula:



wherein:

X_1 and X_2 may be the same or different and each is O or S;

R_1 is alkyl of 1-12 carbon atoms or cycloalkyl of 3-6 carbon atoms, which cycloalkyl may be substituted by one or more alkyl groups or by one or more halogens;

R_2 is hydrogen or alkyl of 1-12 carbon atoms;

R_3 is hydrogen, lower alkyl or halogen;

Z is a linkage selected from -NH-, $-CH_2-$, $-CH_2CH_2-$, $-CH_2NH-$, $NHCH_2-$, $CH_2N(Me)$, $-CH_2CONH-$, $-NHCH_2CO-$, $-CH_2CO-$, $-COCH_2-$, $-CH_2COCH_2-$, $-CH(CH_3)-$, -CH=, and -HC=CH-; and R_7 is C or CH_2C.

17. The compound of claim 16, wherein X_1 and X_2 are O.

18. The compound according to claim 17, wherein R_1 is methyl or ethyl and wherein R_2 is cyclopentyl.

19. The compound of claim 16, wherein Z is $-CH_2NH-$.

20. A pharmaceutical composition comprising a compound having the chemical structure set forth in claim 1.

21. A method of effecting selective PDE IV inhibition in a patient requiring the same, which comprises administering an effective amount of the compound of claim 1.

22. The method of claim 21, wherein said compound is selected from the group consisting of 3-(3-cyclopentyloxy-4-methoxybenzy-lamino)-4-hydroxymethyl pyrazole and 3-(3-cyclopentyloxy-4-methoxybenzylamino)-4-methoxymethylpyrazole.

23. A pharmaceutical composition comprising a compound having the chemical structure set forth in claim 1.

24. The pharmaceutical composition of claim 23, selected from the group consisting of 3-(3-cyclopentyloxy-4-methoxybenzy-lamino)-4-hydroxymethyl pyrazole and 3-(3-cyclopentyloxy-4-methoxybenzylamino)-4-methoxymethylpyrazole.

25. A method of treating a mammal suffering from a disease state selected from the group consisting of asthma, allergies, inflammation, depression, dementia, atopic diseases, rhinitis and disease states associated with abnormally high physiological levels of cytokine, comprising administering an effective amount of the compound of claim 1 or claim 16.

26. The method of claim 25, wherein said compound is selected from the group consisting of 3-(3-cyclopentyloxy-4-methoxy-benzylamino)-4-hydroxymethyl pyrazole and 3-(3-cyclopentyloxy-4-methoxybenzylamino)-4-methoxymethylpyrazole.

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US95/08981

A. CLASSIFICATION OF SUBJECT MATTER

IPC(6) :C07D 231/10, 233/54, 249/04, 249/08; A61K 31/41, 31/415
US CL :Please See Extra Sheet.
According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

U.S. : 548/255, 264.8, 318.5, 326.5, 370.4, 371.4, 372.5; 514/359, 383, 389, 398, 400, 404, 406, 407

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

STN CAS ONLINE, APS (PHOSPHODIESTERASE AND PYRAZOLE)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	EP, A, 0 343 643 (WARNER-LAMBERT COMPANY) 29 November 1989, see page 2.	1-3, 7, 20, 23, 25
X --- Y	US, A, 4,803,216 (APPLETON ET AL.) 07 February 1989, see column 1, lines 22-63.	1-3, 6-8, 11, 20, 23, 25 --------------- 4, 5
Y	US, A, 4,868,183 (KANAI ET AL.) 19 September 1989, see column 1, lines 5-39.	1-3, 7, 20, 23, 25
X	EP, A, 0 511 865 (AMERICAN HOME PRODUCTS COMPANY) 04 November 1992, see pages 3-4.	1-5, 7, 20, 21, 23, 25

[X] Further documents are listed in the continuation of Box C. [ ] See patent family annex.

* Special categories of cited documents:

"A" document defining the general state of the art which is not considered to be part of particular relevance

"E" earlier document published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art

"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
04 SEPTEMBER 1995	05 OCT 1995

Name and mailing address of the ISA/US	Authorized officer
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INTERNATIONAL SEARCH REPORT

International application No.
PCT/US95/08981

C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X --- Y	WO, A, 94/12461 (PFIZER INC.) 09 June 1994, see pages 1-7.	1-13, 20-21, 23, 25 --- 14-19, 22, 24, 26

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US95/08981

A. CLASSIFICATION OF SUBJECT MATTER:
US CL :

548/255, 264.8, 318.5, 326.5, 370.4, 371.4, 372.5; 514/359, 383, 389, 398, 400, 404, 406, 407